

# **Report for 2001KS921B: Measuring Seepage Losses from Waste-treatment Lagoons: A Simplified Water balance Approach for Use By Government Agencies, Consultants, and Industry**

- Articles in Refereed Scientific Journals:
  - Ham, J.M. (1999) Estimating evaporation and seepage from lagoons used to contain animal waste. Trans. ASAE: 42:1303&#64979;1312.
  - Ham, J.M., and DeSutter, T.M. (1999). Seepage losses and nitrogen export from swine waste lagoons: A water balance study. J. Environ. Qual. 28:1090-1099.
  - Ham, J.M. 2002a. Uncertainty analysis of the water balance technique for measuring seepage from animal waste lagoons. J. Environ. Qual. 31:1370&#64979;1379.
  - Ham, J.M. 2002b. Seepage losses from animal waste lagoons: A summary of a four&#64979;year investigation in Kansas. Trans. ASAE. 45:983&#64979;992.

Report Follows:

# Research Report: Measuring Seepage Losses from Waste-treatment Lagoons

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## Research Objectives

Anaerobic lagoons are used throughout Kansas to collect, store, and treat waste from concentrated animal feeding operations (e.g., swine, cattle, dairy). Most lagoons are soil-lined, and concerns have been raised that seepage losses from these facilities could pollute local groundwater. This proposal describes a simplified water balance approach for measuring lagoon seepage that could be used by consultants, state agencies, and industry.

## Methods

Previous research has shown that whole-lagoon seepage rates can be determined by measuring changes in depth ( $\Delta D$ ) and evaporation ( $E$ ) over a 5- to 10-day period (Ham, 1999; Ham and DeSutter, 1999). If waste additions and waste removal is disallowed from a lagoon, then the seepage rate,  $S$ , in mm per day, can be calculated as

$$S = \frac{(-\Delta D + P - E)}{t}$$

where  $P$  is precipitation (mm) and  $t$  is elapsed time (days). Often,  $P$  is negligible, so the crucial measurements are  $\Delta D$  and  $E$ . While there are many ways to measure  $\Delta D$ , the determination of  $E$  from lagoons is challenging. Ham (1999) showed that  $E$  could be determined very accurately using a bulk transfer approach (see Ham Eq. 3), a method which requires the measurement of lagoon surface temperature, wind speed, and humidity near the middle of the lagoon. In this research project, more simplified methods, namely evaporation pans, were tested as an alternative approach for measuring  $E$ .

A portable Class-A-sized evaporation pan was designed and tested (Fig. 1). The pan was made from a 4-ft-diameter stock water tank that had been cut down to a height of 25 cm (10 inches). Liquid levels in the pan were maintained using a remote water level recorder and 55-gal drum filled with waste (Fig. 2). A float-based water level recorder was placed inside the drum to record the change in depth (i.e., evaporation) over time. Deployment of the system consisted of positioning the apparatus on the berm of the lagoon and then filling the pan and drum with waste. During each test of the pan system,  $E$  was simultaneously measured using the bulk transfer approach of Ham (1999). The pan coefficient,  $k_p$ , was computed as the ratio of the actual  $E$  (measured by the Ham method) and evaporation from the pan ( $E_p$ ).

$$E = k_p E_p$$

For the pan method to be viable, the value of  $k_p$  must be known or easily predicted. Pan evaporation is usually larger than actual evaporation; thus,  $k_p$  typically ranges between 0.5 and 0.8.

The pan system was tested at locations in eastern, central, and southwestern Kansas. A test also was conducted in central Oklahoma. At the southwest Kansas site, six tests were

performed over a 12-month period. In addition, the pan made from the stock tank was compared to a commercial Class-A pan made from stainless steel.

## Results to Date

Data show that the pan apparatus itself worked extremely well. In most cases, it was possible to monitor  $E_p$  for 10 to 14 days before the drum reservoir had to be refilled. Evaporation from the stock-tank pan was not significantly different from the commercial Class-A pan during a 30-day test conducted near Manhattan, KS. The pan was easy to deploy, but care had to be taken to avoid any potential leaks in the plumbing. Other possible drawbacks were the accumulation of dust/debris on the pan-water surface and biogas ( $\text{CH}_4$ ,  $\text{CO}_2$ ) bubbles in the hose routing waste from the drum to the pan. The dust problem was worse at cattle feedlots.

Despite the favorable performance of the pan apparatus, the pan coefficients at the different test sites were highly variable. The value of  $k_p$  ranged between 0.35 and 0.8, an unaccepted range of uncertainty. Also, it was difficult to predict the value of  $k_p$  based on time of year or weather conditions. The variation in  $k_p$  was exacerbated by the short duration of the water balance tests (5-10 days) and the large difference in the energy balances of the lagoon and the pan. The problems associated with evaporation pans are well documented in the literature. In the lagoon application, these limitations seem to be even more pronounced. The large temporal and site-to-site variation in  $k_p$  would make it very difficult to predict  $E$  from lagoons using evaporation pans. The uncertainty in  $E$  would cause large errors in the calculation of  $S$ , negating any utility in the approach. Data suggest that the bulk transfer approach of Ham (1999, 2002) is the best approach for measuring  $E$  from lagoons.

Instrumentation was developed that consisted of a meteorological buoy/raft for measuring evaporation, a high-resolution waste-level recorder, and a data acquisition station (Fig. 3) (Ham, 1999; Ham and DeSutter, 1999). The solar-powered system was portable and could be deployed by a single technician. Variations of this instrumentation were used to measure seepage rates from lagoons at swine and cattle feeding operations in Kansas, Oklahoma, and Texas. Data also were collected from a poultry processing plant in Missouri. A formal uncertainty analysis of the technique was completed (Ham, 2002a). Seepage rates from 21 lagoons averaged 1.1 mm/d and ranged from 0.2 to 2.4 mm/d (Ham, 2002b). The average hydraulic conductivity of the compacted liners, as calculated from the seepage data, was  $1.7 \times 10^{-7}$  cm/s. When evaporation rates were low (e.g.,  $< 4$  mm/d), seepage was estimated to within  $\pm 0.5$  mm/d with 95% confidence. A precision of  $\pm 0.25$  mm/d was possible during favorable weather conditions. New research will be presented on measuring seepage with a single 24-h test.

Research is underway to streamline the equipment required for this method, and devise a protocol for its use by state agencies and consultants.

## **References**

- Ham, J.M. (1999) "Estimating evaporation and seepage from lagoons used to contain animal waste." *Trans. ASAE*: 42:1303-1312.
- Ham, J.M., and DeSutter, T.M. (1999). "Seepage losses and nitrogen export from swine waste lagoons: A water balance study." *J. Environ. Qual.* 28:1090-1099.
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## **Information Transfer**

Technology has been transferred to two engineering firms in Kansas. Both of these private contractors can now measure lagoon seepage using research grade techniques identical to those used by Kansas State University. Information was also transferred by the publication of results in peer reviewed journals.

## **Students Supported**

Several undergraduate students were supported by the project. No M.S. or Ph.D. students were employed.

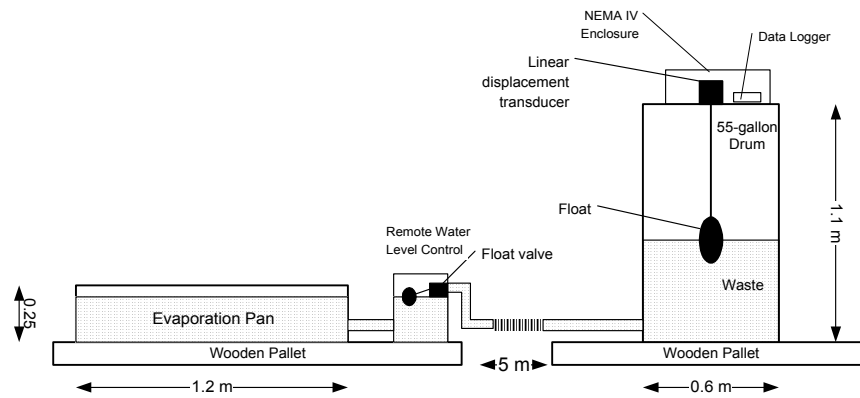


Figure 1. Diagram of the portable Class-A pan system for use at lagoons.



Figure 2. Photograph of the evaporation pan system in the field.



Figure 3. Using the bulk transfer approach of Ham (1999, 2002) to measure seepage from a swine waste lagoon.